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Effect of Planting Methods and Weed Control Treatments on Weed Dynamics, Yield and Economics of Green Gram (*Vigna radiata* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted at the Agronomy Research Farm, College of Agriculture, Gwalior (M.P.), during the 2019 *kharif* season to investigate the effects of different planting methods and weed control treatments on the weeds, growth, yield, and economics of green gram. The field experiment followed a split-plot design with three planting methods as main plot treatments (broadcasting on a flat bed, line sowing on a flat bed, and ridge and furrow) and five weed management practices as sub-plot treatments (Pendimethalin 1000 g/ha, Diclosulam 26 g/ha, Imazethapyr 75 g/ha, hand weeding at 20 and 40 DAS and weedy check), replicated thrice. The experimental field was primarily infested with narrow-leaved weeds such as *Cyperus rotundus, Cynodon dactylon, Echinochloa spp.,* and *Dactyloctenium aegyptium*, and broad-leaved weeds like *Digera arvensis, Celosia argentea, Commelina benghalensis*, and *Phyllanthus niruri*. Among the herbicidal treatments, Imazethapyr at 75 g/ha effectively controlled both narrow-leaved and broad-leaved weeds, resulting in the lowest weed index. The ridge and furrow planting method recorded the highest values in growth parameters, yield attributes, and seed yield, proving to be more remunerative compared to other methods. These findings indicate that the combination of ridge and furrow planting with effective weed management, particularly using Imazethapyr, optimizes green gram productivity and economic returns.

Keywords: Green gram; herbicides; imazethapyr; planting methods; ridge and furrow; weeds.

1. INTRODUCTION

Pulses serve as the primary protein source for India's vegetarian populace and stand as a crucial crop group within the nation's agricultural sector. They not only supply sustenance and forage but also enhance soil fertility and its physical attributes [1]. India holds the distinction of being both the largest consumer and producer of pulses, with its production accounting for 24% globally and cultivated area covering 34% [2]. Cultivation of pulses is adaptable to diverse climatic and soil conditions, playing a pivotal role in ecological balance by facilitating soil phosphorus release and atmospheric nitrogen fixation, thus bolstering soil fertility and promoting sustainability across various farming systems [3]. Furthermore, pulses can serve multiple purposes, functioning as seeds, fodder, or green manure crops [3a,3b,3c].

Green gram (*Vigna radiata* L.) stands out as a significant and widely cultivated pulse crop in India, particularly thriving in arid and semi-arid regions [4]. Locally referred to as "moong," it boasts a nutritional profile comprising approximately 25% protein, 1.3% fat, 3.5% minerals, 4.1% fiber, and 56.7% carbohydrates [5]. Despite its pivotal role in the daily diet, the average productivity of green gram remains notably low in India. Green gram (*Vigna radiata* L.) holds the third position in India in terms of both production, totaling 1.52 million tons, and cultivated area, covering 3.77 million hectares, following chickpea and pigeon pea [6]. Despite its significant importance in the diet, green gram exhibits low productivity in India. The farming community tends to favor spring season cultivation of green gram, finding it more favorable. Conversely, kharif season cultivation is less embraced due to heightened vulnerability to excessive rainfall, insect pests, and diseases. Spring season cultivation of green gram is deemed superior as it ensures a more reliable crop, with fewer incidences of insect pest attacks and no risk from rainfall compared to the rainy season crop [7].

Several factors contribute to the low yield of green gram, including improper planting methods, limited knowledge regarding herbicide application, failure to adhere to appropriate sowing dates, imbalanced fertilizer use, and inadequate pest control measures [8]. Among these, planting pattern and timing of sowing are pivotal. Planting pattern significantly impacts crop yield and growth by influencing moisture utilization and radiation interception [9]. While broadcasting remains a common method of sowing, it is recognized as a major limitation in yield and growth. Optimal production is achieved through line sowing in rows, with raised bed planting methods effectively reducing weed populations and maximizing control efficiency [10]. Cross sowing is also practiced to enhance yield. Various planting patterns significantly affect growth and yield attributes such as plant height, dry matter accumulation, number of branches per plant, pods per plant, seeds per plant, stover, and seed yield [11].

Weed infestation also poses a significant challenge, accounting for yield losses ranging from 50 to 90%, particularly during spring season cultivation [12]. Studies indicate that if weed infestation remains unchecked beyond 20 days after sowing (DAS), it can lead to severe yield reductions of up to 38% or more [13,14]. Losses due to uncontrolled weed growth were reported at 95% in wet seasons and 77% in dry seasons [15]. In more developed agricultural systems, herbicides have largely supplanted mechanical weed control methods [16,17]. However, labor shortages during weeding periods lead to severe field infestations, rendering mechanical weeding ineffective, laborious, and costly [18,19]. Consequently, chemical weed control emerges as a viable and cost-effective alternative for this crop [20,21]. Employing effective herbicides at the appropriate rates can serve as an efficient weed control measure, potentially replacing conventional methods [22,23]. Minimizing weed growth during the crop-weed competition period can result in crop yields comparable to those of weed-free crops [24,25]. Hence, it is imperative to control weeds through any means during crop-weed competition. This paper aims to investigate the effects of planting methods and various weed control practices on the growth and yield of green gram.

2. MATERIALS AND METHODS

The experiment was carried out at the Agronomy Research Farm, College of Agriculture, Gwalior (M. P.), during the 2019 *kharif* season. The experimental site, situated at 26°13' North latitude and 78°14' East longitude, stands at an elevation of 206 meters above mean sea level. It lies in the Northern tract of M.P. and experiences a subtropical climate characterized by extreme temperatures, reaching up to 48°C in summer and dropping to 4.1°C in winter. Annual rainfall typically ranges between 750 to 800 mm, primarily falling from the end of June to the end of September, with occasional showers in the winter months. Weather conditions remained normal throughout the crop season, with average maximum and minimum temperatures of 35.2°C and 24.5°C, respectively. The total rainfall received during the crop-growing period from July to October 2019 was 907.7 mm, although it was noted to be scanty and unevenly distributed.

The soil at the experimental site is sandy clay loam with a pH of 7.57. It has medium levels of organic carbon (0.42%), available nitrogen (183.50 kg/ha), phosphorus (14.48 kg/ha), and potassium (223 kg/ha).

The experiment utilized a split-plot design replicated thrice, with three planting methods as main plot treatments (broadcasting in flat bed, line sowing in flat bed, ridge and furrow) and five weed management practices as sub-plot treatments (pendimethalin 1000 g/ha, diclosulam 26 g/ha, imazethapyr 75 g/ha, hand weeding at 20 and 40 days after sowing, and a weedy check). Each experimental plot measured 5 m x 3.60 m.

The green gram variety employed in the experiment was TJM 3, with a recommended seed rate of 20 kg/ha. Seeds were manually sown in the field on July 24, 2019. After proper field preparation and layout, fertilizers were applied at the rate of 20 kg/ha of nitrogen, 50 kg/ha of P_2O_5, and 20 kg/ha of K_2O, with the entire quantity applied as basal dose to the crop. Urea, single super phosphate, and muriate of potash served as the sources of nitrogen, phosphorus, and potassium, respectively. Pre-emergence application of pendimethalin 1000 g/ha and diclosulam 26 g/ha was conducted within 24 hours after sowing, while post-emergence application of imazethapyr 75 g/ha was performed at 19 days after sowing to control associated weeds. Hand weeding was carried out at 20 and 40 days after sowing using khurpi. The weeds in the weedy check treatment were left uncontrolled and allowed to grow alongside the crop until harvest. Irrigation was applied as per the crop's requirement. Plant height was recorded for five plants per plot in centimeters from the ground level to the tip of the growing point using a scale. Weed species were randomly counted using one square meter quadrates from each plot. The weed index, expressed as a percentage, was calculated at harvest according to the formula by Gill [26].

$$\text{Weed index (\%)} = \frac{(X - Y) \times 100}{X}$$

Where,

X = Yield from maximum weed free plot

Y = Yield from other treated plot

To determine the number of pods per plant, all pods were collected from three tagged plants, carefully removed by hand, and the seeds were separated from the straw and counted to obtain an average. After threshing, the seed and stover were separated and weighed per plot, and the seed yield per hectare in kilograms was calculated by multiplying with the conversion factor. Harvest index was calculated using the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (seed)}}{\text{Biological yield (seed+straw)}} X\ 100$$

3. RESULTS AND DISCUSSION

3.1 Weed Flora

The experimental field was entirely invaded with mixed weed flora consisting of narrow and broad-leaved weeds. Among the total weeds, narrow-leaved weeds were more prominent than broad-leaved weeds. Major weeds observed in the experimental field were *Cyperus rotundus, Cynodon dactylon, Echinochloa Spp., Dactylactenium aegyptium* among narrow-leaved weeds while *Digera arvensis, Celosia argentea, Commelina benghalensis, Phyllanthus niruri* were the most common in broad-leaved weeds. Similar findings were reported by Kade et al [27,28].

3.2 Weed Density (no./m^2)

There was no significant variation observed in the density of all weed species at 40 days after sowing (DAS) across different planting methods (Table 1). In contrast, significant differences were observed in weed density among various weed control treatments. The population of weeds was notably higher in the weedy check treatment compared to all herbicidal treatments, including two hand-weeding sessions at 20 and 40 DAS. This finding underscores the importance of implementing effective weed control measures to mitigate weed competition and minimize yield losses in green gram cultivation. Among the herbicidal treatments, Imazethapyr 75 g/ha demonstrated the highest efficacy in reducing the population of both narrow and broad-leaved weeds, with results similar to Diclosulam 26 g/ha and Pendimethalin 1000 g/ha. These findings are consistent with previous research highlighting the effectiveness of these herbicides in weed suppression in various crops [29]. However, it is essential to consider factors such as herbicide resistance and environmental impact when selecting herbicidal weed control strategies [30]. Interestingly, complete control of all weeds was achieved with two hand-weeding sessions at 20 and 40 DAS. The hand-weeding method proved highly effective in reducing weed populations to negligible levels. While hand weeding can be labor-intensive and costly, particularly in large-scale agricultural operations, these results highlight its efficacy as a weed management option, especially in situations where herbicide use may be limited or undesirable [31,32]. The non-significant interaction effect of planting methods and herbicides on weed population further supports the results that planting methods did not significantly interact with the efficacy of herbicidal weed control treatments in influencing weed density.

3.3 Weed Index (%)

The weed index varied significantly with different planting methods (Fig. 1). Crops planted using the ridge and furrow method had the lowest weed index at 14.01%, outperforming other sowing techniques. Line sowing on flat beds also had a relatively low weed index of 20.52%, compared to broadcasting on flat beds. Among the weed control treatments, the weed index was highest at 47.54% in the untreated (weedy check) plots, significantly higher than in all herbicide-treated plots, including those with two hand weeding sessions at 20 and 40 days after sowing (DAS). Among the herbicides, Imazethapyr at 75 g/ha was the most effective, with a weed index of 18.38%, closely followed by Diclosulam at 26 g/ha and Pendimethalin at 1000 g/ha. The interaction between planting methods and herbicides on the weed index was found to be non-significant.

3.4 Herbicidal Efficiency Index (%)

Crops sown using the broadcasting method on a flat bed exhibited the highest herbicidal efficiency index at 2.196%, surpassing all other treatments (Fig. 2). Line sowing on a flat bed also showed a relatively high herbicidal efficiency index of 1.362%, compared to the 0.829% observed with the ridge and furrow method. This indicated that the broadcasting method may provide more uniform herbicide distribution and better coverage, resulting in more effective weed control. The even dispersion of seeds in broadcasting likely enhances herbicide contact with the weed flora, thereby increasing the herbicidal efficiency index. Various weed control treatments demonstrated no significant variation in herbicidal efficiency index. Additionally, the interaction between planting methods and herbicides on the herbicidal efficiency index was found to be non-significant.

Table 1. Effect of planting methods and weed control methods on weed density (no./m²) in green gram at 40 DAS

Treatments	*Cyperus rotundus*	*Cynodon dactylon*	*Echinochloa Spp.*	*Dactylactonium ageptium*	*Digera arvensis*	*Celosia argentea*	*Commelina beghalensis*	*Phyllanthus niruri*
Planting Methods (P)								
Broadcasting in flat bed	2.44 (6.95)	2.30 (6.15)	2.02 (4.71)	2.21 (5.55)	1.85 (4.16)	1.77 (3.55)	1.64 (2.71)	1.71 (3.15)
Line sowing in flat bed	2.36 (6.53)	2.21 (5.69)	1.92 (4.29)	2.11 (5.09)	1.72 (3.69)	1.65 (3.13)	1.52 (2.29)	1.59 (2.73)
Ridge and furrow	2.26 (6.07)	2.10 (5.20)	1.77 (3.80)	1.99 (4.60)	1.59 (3.33)	1.51 (2.73)	1.41 (1.93)	1.43 (2.31)
SEm±	0.05	0.03	0.06	0.07	0.05	0.08	0.02	0.06
C.D. (at 5%)	NS	NS	NS	NS	NS	NS	0.10	NS
Weed Control Methods (W)								
Pendimethalin 1000 g/ha	2.22 (4.48)	2.06 (3.81)	1.70 (2.48)	1.98 (3.48)	1.40 (1.56)	1.40 (1.56)	1.42 (1.56)	1.40 (1.56)
Diclosulam 26 g/ha	2.17 (4.30)	2.01 (3.63)	1.63 (2.30)	1.93 (3.30)	1.31 (1.37)	1.31 (1.37)	1.36 (1.37)	1.31 (1.37)
Imazethapyr 75 g/ha	2.22 (4.44)	2.01 (3.59)	1.63 (2.19)	1.93 (3.26)	1.32 (1.33)	1.36 (1.41)	1.31 (1.26)	1.34 (1.37)
Hand weeding	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
Weedy check	4.46(19.37)	4.23 (17.37)	3.85 (14.37)	3.98 (15.37)	3.85(14.37)	3.44(11.37)	2.80 (7.37)	3.14 (9.37)
SEm±	0.06	0.07	0.08	0.07	0.08	0.09	0.05	0.09
C.D. (at 5%)	0.18	0.21	0.25	0.20	0.25	0.25	0.15	0.28
Interaction (PxW)	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of planting methods and weed control methods on growth parameters and yield attributing trait in green gram at 40 DAS

Treatments	Plant Height (cm)	No. of Branches/Plant	Root Nodules/Plant	Pods/Plant
Planting Methods (P)				
Broadcasting in flat bed	26.6	4.85	21.4	5.50
Line sowing in flat bed	30.4	5.62	25.1	6.62
Ridge and furrow	32.8	5.41	25.5	6.68
SEm±	0.51	0.14	0.56	0.09
C.D. (at 5%)	1.99	0.55	2.19	0.35
Weed Control Methods (W)				
Pendimethalin 1000 g/ha	29.2	5.30	23.3	6.09
Diclosulam 26 g/ha	31.2	5.37	25.2	6.48
Imazethapyr 75 g/ha	32.0	5.70	25.6	6.93
Hand weeding	31.0	5.52	26.1	6.90
Weedy check	26.3	4.59	19.8	4.93

Treatments	Plant Height (cm)	No. of Branches/Plant	Root Nodules/Plant	Pods/Plant
SEm±	0.95	0.18	0.76	0.21
C.D. (at 5%)	2.76	0.53	2.20	0.60
Interaction (PxW)	NS	NS	NS	NS

Table 3. Effect of planting methods and weed control methods on seed yield, harvest index and economics in green gram

Treatments	Seed Yield (kg/ha)	Harvest Index (%)	Net Monetary Returns (Rs/ha)	B:C Ratio
Planting Methods (P)				
Broadcasting in flat bed	615	32.44	6111	1.26
Line sowing in flat bed	723	33.64	11273	1.48
Ridge and furrow	808	34.72	15296	1.64
SEm±	16.63	-	-	-
C.D. (at 5%)	63.87	-	-	-
Weed Control Methods (W)				
Pendimethalin 1000 g/ha	738	33.58	13827	1.61
Diclosulam 26 g/ha	755	33.81	13967	1.60
Imazethapyr 75 g/ha	767	34.27	15181	1.67
Hand weeding	825	34.76	7954	1.24
Weedy check	493	31.58	3537	1.17
SEm±	14.09	-	-	-
C.D. (at 5%)	41.29	-	-	-
Interaction (PxW)	NS	-	-	-

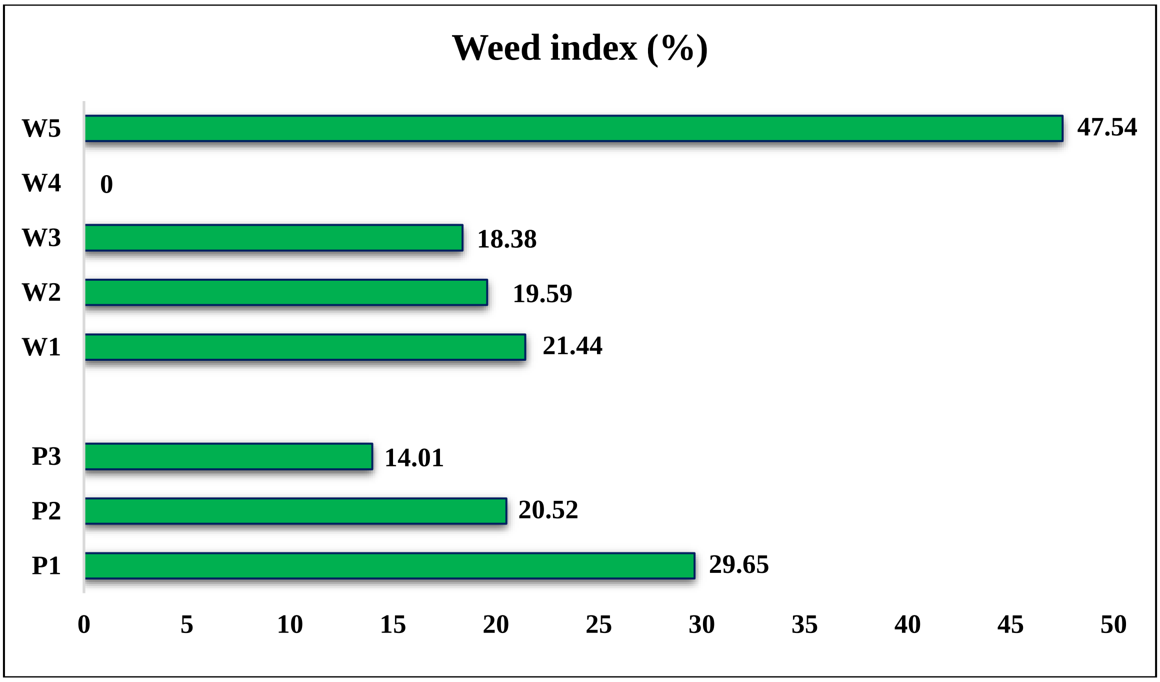

Fig. 1. Effect of planting methods and weed control methods on weed index (%) in green gram

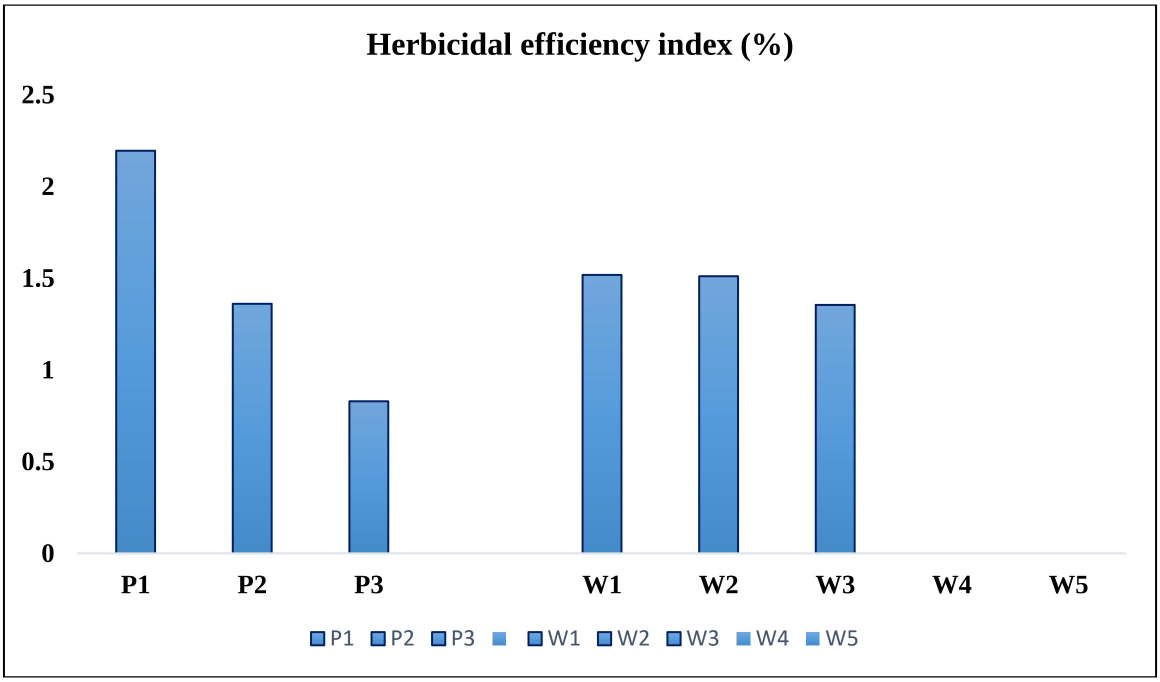

Fig. 2. Effect of planting methods and weed control methods on herbicidal efficiency index (%) in green gram

3.5 Growth Parameters and Yield Attributing Trait

The different planting methods significantly influenced growth parameters such as plant height, number of branches, number of root nodules, and yield traits like pods per plant at 40 DAS (Table 2). The ridge and furrow method resulted in the highest plant height (32.88 cm), number of branches (5.62), number of root nodules (25.59), and pods per plant (6.68) compared to other methods. The improved soil aeration and drainage in the ridges likely enhance root development and nutrient uptake, leading to more robust plant growth. Additionally, the distinct spatial arrangement reduces competition among plants for resources such as light, water, and nutrients, thereby promoting better overall growth and yield attributes [33]. Line sowing on a flat bed showed significantly higher values for these parameters than broadcasting on a flat bed [34]. All growth parameters and yield traits were also significantly affected by the different weed control treatments at 40 DAS. The results clearly indicate that all weed control treatments led to significantly higher growth parameters and yield traits compared to the untreated control. The highest values were observed with two hand weedings at 20 and 40 days after sowing (DAS). Among herbicide treatments, Imazethapyr at 75 g/ha resulted in the highest plant height (32.03 cm), number of branches (5.70), number of root nodules (25.68), and pods per plant (6.93), comparable to the other three herbicide treatments but significantly superior to the untreated control. The efficacy of Imazethapyr can be attributed to its broad-spectrum activity, which effectively controls a wide range of weed species, thereby reducing competition and promoting better crop growth. The comparable performance of other herbicide treatments indicates that they are also effective in managing weed pressure, but Imazethapyr's specific mode of action and residual activity might offer a slight advantage in sustaining crop growth [35,36]. The lowest values for these parameters were found in the untreated control, which was significantly lower than all other herbicide treatments [37]. The interaction between planting methods and weed control treatments on all growth parameters and yield traits was found to be non-significant at 40 DAS.

3.6 Seed Yield (kg/ha)

Different planting methods and weed control treatments significantly influenced seed yield (Table 3). The highest seed yield (808 kg/ha) was observed with the ridge and furrow method, which was significantly higher than the line sowing on a flat bed (723 kg/ha) and broadcasting on a flat bed (615 kg/ha). The ridge and furrow method likely promotes better root development and nutrient uptake due to improved soil aeration and drainage. These conditions can enhance plant health and productivity, resulting in higher seed yields. The spatial arrangement in this method also reduces plant competition for resources such as light, water, and nutrients, allowing each plant to grow more robustly [38]. Conversely, the broadcasting method often leads to uneven seed distribution and greater intra-species competition, which can inhibit growth and reduce yield. Weed control treatments resulted in higher seed yields per hectare compared to the untreated control. The highest seed yield (825 kg/ha) was achieved with two hand weedings at 20 and 40 days after sowing (DAS). Among the herbicides, Imazethapyr at 75 g/ha was the most effective, comparable to Diclosulam at 26 g/ha and Pendimethalin at 1000 g/ha. The broad-spectrum activity of Imazethapyr and residual control of a wide range of weed species likely contribute to its effectiveness. By effectively managing weed populations, herbicides minimize competition and enhance resource availability for the crop, leading to higher yields. The lowest seed yield (493 kg/ha) was recorded in the untreated control. The interaction between planting methods and weed control treatments on seed yield was found to be non-significant. These findings are in confirmation with Singh et al [39,40].

3.7 Harvest Index (%)

The ridge and furrow method resulted in the highest harvest index (34.72%), surpassing the other two sowing methods (Table 3). Line sowing on a flat bed also achieved a higher harvest index (33.64%) compared to broadcasting on a flat bed (32.44%). Weed control treatments led to a higher harvest index compared to the untreated control. The highest harvest index was observed with Imazethapyr at 75 g/ha (34.27%), followed by Diclosulam at 26 g/ha and Pendimethalin at 1000 g/ha. The lowest harvest index (31.58%) was recorded in the untreated control. Similar findings have been reported by Mirjha et al [41].

3.8 Economics

Crops sown using the ridge and furrow method achieved the highest net monetary return (Rs. 15,296/ha) and B:C ratio (1.64), outperforming the other two sowing methods. Line sowing on a flat bed also recorded a significantly higher net monetary return (Rs. 11,273/ha) and B:C ratio (1.48) compared to broadcasting on a flat bed (Rs. 6,111/ha; 1.26). Among weed control treatments, Imazethapyr at 75 g/ha resulted in the highest net monetary return (Rs. 15,181/ha) and B:C ratio (1.67), followed by Diclosulam at 26 g/ha and Pendimethalin at 1000 g/ha. The lowest net monetary return (Rs. 3,537/ha) and B:C ratio (1.17) was observed in the untreated control. These findings corroborate with Bahar et al [42].

4. CONCLUSION

In conclusion, Imazethapyr at 75 g/ha proved to be the most effective weed control treatment for moongbean, resulting in the lowest weed index. Among the planting methods, the ridge and furrow method demonstrated superior performance, achieving the highest values in growth parameters, yield attributes, seed yield, net monetary returns, and benefit-cost ratio. This combination of effective weed management and optimal planting techniques maximizes productivity and profitability for moongbean cultivation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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